AIC-212
November, 1948

CONCENTRATING CITRUS JUICES BY THE VACUUM METHOD

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Part 1* - Selection of fruit, the equipment used and processing are described in the first part of this article. Control, sanitation, packing and costs are to be discussed in the second instalment.

The juice of oranges, grapefruit, lemons and limes can be concentrated to as little as one-tenth of the original volume by evaporation of water under high vacuum. Concentrates protected from contact with air in waxed barrels or in tinplate or glass containers, can be held at 32 degrees F. for as long as two years.

These concentrates are used in carbonated beverages and confections, or they may be reconstituted to the original volume for consumption. Concentrates containing the juice solids from as much as four tons of fruit may be stored and shipped in a 50-gallon barrel, an important consideration when containers are scarce or shipping facilities are inadequate.

In order to minimize impairment of flavor, color and food value, every detail of preparation, packing and handling must be controlled. This paper describes methods suitable for production of citrus concentrates on a commercial scale.

Equipment

Stainless steel, glass, glass-enameled ("glass-lined") steel, oil-resistant rubber, stainless aluminum alloy or similar inert materials should be used for equipment coming in contact with juice or concentrates.

Stainless steel (18-8) alloy is widely used for tubing, tanks, valves, fittings and pumps. For lemon and lime concentrates, stainless steel with 1 to 4 percent of molybdenum is preferred. Some acid-resisting stainless alloys also contain less than 1 percent of columbium.

Surfaces of equipment coming in contact with the juice should be smooth and free from crevices to facilitate cleaning and avoid the hazard of introducing spoilage organisms. Approved dairy equipment is well adapted to cleaning and inspection.

Selecting Fruit

Clean, sound, ripe fruit of suitable varieties should be used. Spoiled, frost-

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* Agricultural Chemical Research Division Contribution No. 97.

Published in "Food Industries" 15, May, 62-4, 122 and June, 64-66, 110-111 (1943)

damaged, and over - or under-mature fruit must be eliminated. It should also be borne in mind that juice flavor is affected by the location and management of groves. Only juice of excellent flavor should be used for concentrates. Scales for weighing fruit on trucks or conveyors at the concentrating plant are necessary for the determination of fruit costs and juice yields.

Oranges. Juice yields vary from 70 to 105 gal. per ton. Valencias are generally preferred for flavor, color, and stability. Navel orange concentrate may deterioate in color and flavor unless fully ripe fruit is used and the juice is flash-pasteurized within a few seconds after extraction. Juice yields from Navel Oranges are low. However, the high vitamin content of this variety has led to extensive use in recent years. Temple, Mediterranean, Florida Seedling and Early Round varieties are also used, but Mandarin varieties are not.

Grapefruit. Juice yields vary from 70 to 90 gal. per ton. Marsh and Duncan varieties are used. Because of its neutral character, grapefruit concentrate is used with stronger fruit flavors to balance fruit character.

Lemons. Juice yields vary from 70 to 95 gal. per ton, depending upon the ripeness of the fruit and whether it has been harvested tree-ripe or "cured" in cool storage. Eureka and Lisbon varieties are preferred. Lemon juice concentrated to 30 percent citric acid content is finding a wide market as a superior substitute for citric acid in beverage manufacture.

Limes - Juice yields vary from 60 to 90 gal. per ton. West Indian, Baers' Seedless, Persian and other varieties may be used.

Extracting the Juice.

After adequate washing and sorting of fruit, the juice can be extracted by reaming or pressing, or a combination of these methods. Simple, rugged extractors should be designed to avoid grinding action which may incorporate excessive pectin, and cause jelling of concentrates. If juice is pressed from unpeeled fruit, the oil may be substantially separated by passing the juice through a high-speed centrifuge. Oil remaining in the juice is largely volatilized during concentration.

Screening.

Seeds and membrane are separated from the juice in tumbling screens or in cyclone finishers with perforated screens having 0.020-in. openings.

Deaerating.

Removal of 90 percent of entrapped air by agitation of juice under a 29-in. vacuum has been observed to improve vitamin C retention by approximately 10 percent. Deaerators of high capacity and efficiency are commercially available.

Pasteurizing.

Flash-heating the juice without delay in a high-velocity heat exchanger to 200 deg F. is effective for killing yeasts and inactivating pectin, enzymes. Damage to flavor may be minimized in pasteurizers where uniform juice velocities greater than 8 ft. per second, and heat transfer rates as high as 300 b.t.u. per hour per square foot, per degree difference in tempera ture (1,2) are maintained.

Pasteurizers with high heat-exchange rates are designed either with small, flattened or coiled tubes, or tubes containing continuous helical baffles to agitate the juice. In plate-type exchangers, the juice and heating medium flow between plates separated by only a small fraction of an inch.

If steam is used for heating, the juice should be directed upward and the steam and condensate downward through restricted channels to secure uniform counterflow heat exchange, which improves efficiency and facilitates control.

In high-velocity heat exchangers of the coiled flattened-tube type, it is possible to heat grapefruit juice under pressure to temperatures as high as 240 deg.F. with less change in flavor than is caused by heating to 180 deg. F. in low-velocity heat exchangers with tubes of large diameter.

If juice is heated rapidly to 205 deg. F. in an exchanger of suitable design and immediately cooled either by introduction into a vacuum chamber or by passage through a water-jacketed cooling tube, undersirable changes in flavor can be largely avoided.

Buffering.

The equivalent of 200 parts per million of sodium citrate or sodium bisulphite is sometimes added to pasteurized juice accumulated for concentrating. Sulphurous acid aids in retarding oxidation and the development of spoilage organisms. Uncombined sulphur dioxide is substantially removed during concentration under vacuum.

Residual sodium citrate aids in inhibiting jelling of concentrates containing acid, pectin and 65 percent or more of soluble solids.

At one time, many concentrators added sugar to citrus juices before concentrating; but this practice has been discontinued except for certain special products.

Traces of sodium chloride are sometimes added to orange concentrates to modify the taste.

Concentrating.

Vacuum concentration is accomplished by evaporating water and other volatile constituents in vacuum pans which vary in methods of supplying heat, condensing vapors and producing a vacuum.

Although multiple-effect evaporators permit savings in fuel, single-effect equipment has been more commonly employed to facilitate close control at low temperatures and avoid overcooking.

A simple design is the jacketed pan, consisting of a cylindrical vessel, the bottom portion of which is surrounded by a steam jacket. Accurate thermometers, vacuum gauges and level indicators make it possible for skilled operators to produce concentrates of good quality in batch operation, provided the level of juice and concentrate is always maintained above the top of the steam jacket. If a vacuum is maintained equivalent to 29 in. of mercury, temperatures in excess of 115 deg. F. can be avoided.

A tight-closing manhole is necessary in this and other vacuum pans to permit thorough cleaning. The evaporative capacity of the jacketed pan is limited because of the small heat-exchange surface.

Pans with internal heaters of flattened coil or vertical tube Claassen type have more heat-exchange surface and correspondingly increased evaporative capacity. A central downtake is standard, and circulation is induced by convection.

These so-called "calandria" pans have a higher capacity than jacketed pans but some difficulty may be experienced with viscous concentrates.

Circulating evaporators with external steam chambers containing vertical heating tubes of small diameter are most widely used for large citrus juice concentrating operations. Designs of such evaporators vary. Circulation may be obtained by convection, but positive control by means of high-speed centrifugal pumps is generally preferred.

The circulating pump is located below the flash chamber to force the juice upward through the outside heating element. An outlet valve and butterfly choke valve in the line between the pump and heater make it possible to remove the concentrate without breaking the vacuum and thus permit continuous operation. Single-strength juice is admitted at the bottom of the heating element, and when the juice has reached the desired degree of concentration it can be pumped out without suspending operation.

Thermometers, located just above the heater and in the juice at the bottom of the flash chamber, permit the operator to observe maximum and minimum temperatures and maintain a constant differential of from 5 to 10 deg. Juice entering the flash chamber from the heater is directed downward, tangentially to the wall, to avoid entrainment losses.

Heat is supplied by admitting steam, at pressures ranging from 1 to 10 lb. per square inch, to the chest surrounding the vertical-tube heat exchanger. Steam from plant lines maintained at higher pressures may first be used to operate turbine-driven pumps or other equipment, provided the steam requirement of the turbine is less than that of the evaporator. Under this condition, the turbine operates efficiently, discharging into the partial vacuum maintained by pumping condensate from the heat exchanger. Small quantities of additional steam can be admitted to the heater through a reducing valve. When the steam requirement of

the turbine exceeds that of the heater, it is necessary to discharge a portion of the steam to atmosphere, necessitating excessive back pressure upon the turbine and reducing its efficiency.

A swing check valve at the top of the steam chest vents steam when the steam pressure exceeds atmospheric but prevents the admission of air when the inside pressure is below atmospheric. A condensate pump at the bottom of the heater returns condensate to the boiler and may be used to maintain a reduced pressure in the steam chest, increasing turbine efficiency and permitting the control of temperatures below 212 deg. F.

There has been a trend toward higher vacuum and lower temperature, using equipment of high capacity designed to minimize the hazard of local overheating or scorching.

The necessity, however, of supplying cooling water 20 deg. lower in temperature than the vapor has imposed limitations upon practicable operating temperatures. In subtropical citrus sections, refrigeration is usually necessary to supply condensing water at temperatures below 70 deg. F.

Multiple-effect evaporators may be of the Claassen or of the outside heater type. Vapors from the first effect are drawn into the steam chest heater for the second effect, which thus serves as a surface condenser. When properly designed and operated, this type of equipment may permit substantial savings in fuel.

Condensing Vapors and Securing Vacuum.

Vapors can be condensed and a vacuum obtained by several methods. Abundant cool condensing water at nominal cost is necessary. Surface condensers are used only on small evaporators and in multiple-effect equipment. Barometric countercurrent condensers, and parallel-flow water-jet condensers are widely used.

Multiple-jet condensers are simple in design and operation. Cool water under pressure is projected downward through a ring of nozzles at the center of the condensing chamber, being aimed into the throat of the wet leg and dropping 35 ft. to a hot well.

Vapors from the evaporator are drawn into the top of the condensing chamber at high velocity. Steam is condensed, and noncondensables are carried down the leg by entrainment. The moderate cost of this equipment favors its use for small installations where abundant cooling water can be supplied at nominal cost. If the vapors contain appreciable quantities of uncondensable gases, this type of condenser is not adapted for maintaining the high vacuum now required.

Barometric condensers, with separate vacuum pumps for removing noncondensables, are used for most large juice evaporators. In equipment of this type, vapors from the concentrator enter the bottom of the condensing chamber. Condensing water enters near the top, and intimate mixture is insured by baffles. Condensing water and condensate drop through a 35-ft. barometric leg to a hot well, or if

more convenient may be pumped out. Uncondensables are drawn from the top of the condenser by a vacuum pump which usually consists of a two - to four-stage steam-jet ejector system with inter-condensers between the stages. Dry steam at uniform pressure is necessary. With such a system it is possible to secure a vacuum permitting operation of evaporators at 80 deg. F., provided cooling water is supplied to the condenser at 50 deg. F.

When it is impossible to supply condensing water 30 deg. cooler than the desired pan operating temperatures, a one- or two-stage steam-jet vacuum booster may be inserted in the vapor stack. This increases requirements for condenser water and steam.

Other methods of condensing vapors and securing a vacuum are modifications of those described. The condenser may be located in the top of the flash chamber with resulting saving in initial costs.

As long as citrus concentrates were used almost exclusively as carbonated beverage bases, maximum temperatures of 115 deg. F. were considered satisfactory. Increasing interest in the production of concentrates to replace fresh and canned juice, and permit savings in containers and shipping facilities, makes it desirable to maintain maximum concentrating temperatures below 100 deg. F.

The effect of heat upon flavor of citrus juices and concentrates depends upon both time and temperature. Prolonged heating and local overheating cause trouble more frequently than excessive temperatures. Equipment must be designed to insure rapid, uniform application of heat, agitation of juice in contact with heat-exchange surfaces, avoidance of drying upon heated surfaces, and quick cooling to temperatures below 100 deg. F.

Single-Pass Continuous Concentrating.

Efforts have been made to design single-pass concentrators suitable for handling citrus juices without scorching. At 100 deg. F., the heat of liquid is only one-twentieth as great as the latent heat of evaporation. It is therefore impossible to supply sufficient heat to the juice before it enters the flash chamber to permit concentration from initial soluble solids of 10 percent to final soluble solids of 70 percent.

In order to supply heat continuously to the flowing mixture of juice and vapor without causing scorching, efforts have been made to use a heat-exchange medium at very low temperature and to use equipment designed to cause high speed, uniform flow over all heat-exchange surfaces. Because of the viscosity and susceptibility of citrus concentrates to scorching, difficulties must be overcome before commercial applications will be practicable.

Ester Recovery.

Fractions of condensates containing flavoring esters, and so forth, are commonly returned to concentrates made from grape and apple juices. The resulting improvement in flavor justifies the cost. Efforts to return fractions of condensates to citrus juice concentrates have usually resulted in off-flavors which offset any improvement which might otherwise have been obtained through the presence of the flavoring constituents. However, it is not improbable that further research may develop methods for improving citrus concentrates by returning certain fractions of the early distillate.

Recovery of ester fractions is impossible from condensers in which they are mixed with condensing water. The esters might be recovered in a surface condenser attached to a small single-pass evaporator inserted between the juice pasteurizer and the vacuum pan, using the heat of the liquid to effect the evaporation.

Until some development permits the return of volatile juice constituents, the flavor of citrus concentrates can best be improved by adding small amounts (e.g., much less than 1 percent) of cold-pressed peel oil concentrated under a high vacuum to one-third of its original volume. The least stable constituents of the oil are thus distilled off, and are sold in the trade as "terpenes." The concentrated cold-pressed oil remaining behind is improved in stability and may be mixed with the citrus concentrates in the form of an alcholic solution or emulsion immediately before the concentrate is removed from the vacuum pan.

PART II

The value of citrus concentrates is based upon: (1) Ascorbic acid content, expressed in milligrams per gram; (2) anhydrous citric acid; expressed in percent by weight; (3) soluble solids estimated from: (a) the refractive index, or (b) the specific gravity expressed in degrees Brix; (4) flavor, color, texture and keeping quality.

The Association of Official Agricultural Chemists method for determining soluble solids is by drying in a vacuum oven at 70 deg. C. (158 deg. F.). Obviously, such a method is not adapted to plant control. Experience with various citrus fruits enables the vacuum pan operator to use a refractometer in effectively controlling the removal of concentrates from the evaporator. Tables have been prepared showing the refractive index of cane-sugar solutions of any concentration. In order to obviate the need for reference to tables, refractometers have been calibrated so that the percentage of sugar in pure sucrose sirups may be read directly at a standard temperature; and corrections may be applied if the temperature varies from that for which the instrument was calibrated.

Table I shows typical analyses of citrus juices. It will be noted that sugar constitutes 23 to 71 percent of the total solids present in these juices. Solutions of the other juice constituents have refractive indexes and specific gravities which vary from those of pure sugar solutions.

As the sale of orange and grapefruit concentrates has been based upon density expressed in terms of degrees Brix, it is necessary to determine or estimate this property of the concentrate. At concentrations above 50 deg. Brix, orange and grapefruit juices become too viscous for accurate determination of the specific gravity by means of a spindle hydrometer or by a Westphal balance. Dilution is an unreliable method for estimating the Brix because no tables are available for determining the relation of dilution to density on such complex mixtures as citrus juices. In order to arrive at a practicable basis for operation, Stevens and Baier (3) have published tables based upon a study of prepared mixtures of water, sugar and citric acid, and have determined the relation between specific gravity, refractive index, and soluble solids. These tables are useful for orange and grapefruit concentrates in the range of from 60 to 70 percent of soluble solids. They are less applicable to concentrates above 70 percent of soluble solids, and they do not apply to lemon and lime juice concentrates. Fortunately, the specific gravity of lemon and lime juice concentrates at 30 percent citric acid content, can be measured directly by spindle or Westphal balance without dilution; and each concentrator can easily prepare his own tables for correcting refractometer readings.

A convenient method for estimating the ascorbic acid content of fresh citrus juice and concentrates is described by Stevens (4). Iodine titration may not be used in juices containing sulphur dioxide, or in the presence of metallic salts such as may be dissolved from cans during storage, but is inexpensive and convenient for routine plant-control tests of fresh juice and concentrates.

For accurate checking of ascorbic acid content, dependence is placed upon titration with 2,6-dichlorophenolindophenol in the presence of metaphosphoric acid and glacial acetic acid, employing a modification of methods described by Musulin and King (5), Bessey (6) and Morrel (7), using pure ascorbic acid for standardization of the dye.

When losses in excess of 10 percent of ascorbic acid are encountered, faulty plant procedure should be sought and corrected. These losses may be caused by:

1. Oxidation of ascorbic acid during heating or storage of the juice while in contact with atmospheric oxygen incorporated during extraction, screening or handling.

2. Oxidation of ascorbic acid following inefficient deaeration, when attempts are made to operate deaerators at a vacuum less than 27 in. or on larger volumes of juice than the equipment can efficiently deaerate. In general, the higher the vacuum and the greater the agitation of the juice, the greater the efficiency and capacity of the deaerators.

3. Dissolved copper salts materially accelerate the oxidation of ascorbic acid. Permitting the juice to come in contact with any copper alloy, with zinc, or with plain iron equipment will cause avoidable losses of ascorbic acid.

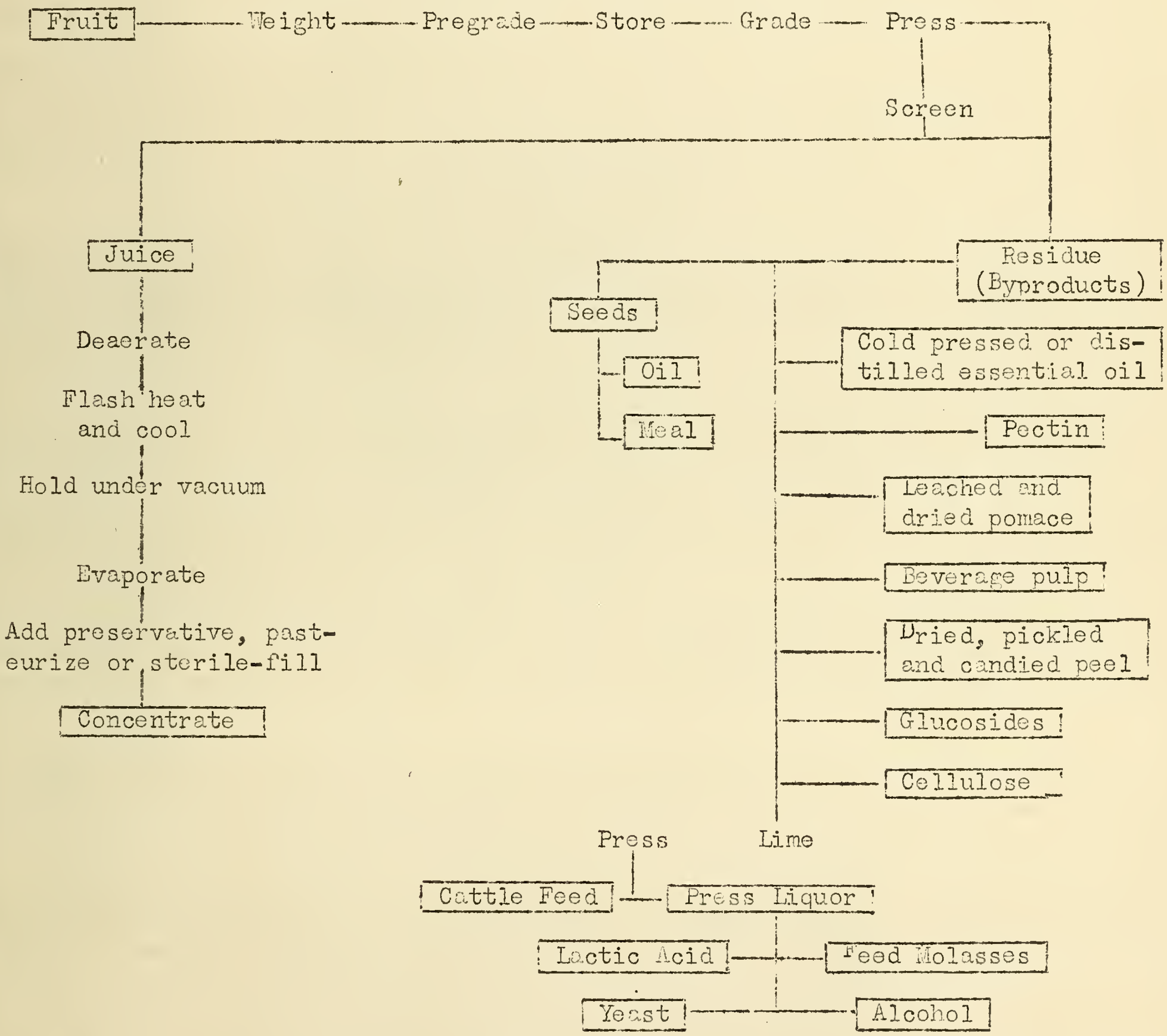
4. The action of living microorganisms may cause losses of ascorbic acid. The remedy lies in improved sorting of fruit and better plant sanitation. Losses from this cause may be considered as warning of a hazard of spoilage of concentrates.

Table I. Analyses of Citrus Juices by A. O. A. C. Methods

Constituents	Fruit: Orange (percent)	Lemon (percent)	Grapefruit (percent)
Sugars	8.4	2.2	7.2
Acid (as citric)	1.1	5.3	1.4
Fat	0.2	0.3	0.2
Protein (N x 6.25)	0.7	0.6	0.6
Ash	0.5	0.5	0.5
Other solids	0.9	0.6	0.6
Total solids	11.8	9.5	10.5
Sugar, Percentage of total solids	71.2	23.2	68.6

Note: The composition of citrus fruits changes with ripeness, variety, growing conditions, etc. These analyses were selected from the writer's notes as typical.

PROCESS OF CONCENTRATING CITRUS JUICES



Complete laboratory records should be maintained on each batch or day's production. Yields of single-strength juice are expressed in gallons per ton of fruit, and yields of concentrate are calculated from the number of gallons of single-strength juice required to produce each gallon of concentrate. This ratio varies not as the Brix values or percentages of soluble solids, but inversely as the weight of soluble solids in each gallon of the initial and final product.

Table II shows the relation of the weight per gallon of sirup, juice or concentrate to the specific gravity and Brix. By reference to the weight per gallon, it is possible to estimate the weight of soluble solids in each gallon of juice or concentrate, provided the Brix is assumed to equal the percentage of soluble solids. The error resulting from this assumption is small, less than the normal shrinkage in processing.

If A is the percentage of soluble solids (Brix), B is the weight per gallon of juice or concentrate, and C is the weight of soluble solids per gallon, then

$$A \times B = C$$

To illustrate, concentrating lemon juice form 9 deg. Brix to 46 deg. Brix (30 percent citric acid by weight):

$0.09 \times 8.6 = 0.774$ lb. of solids in each gallon of single-strength juice;

$0.46 \times 10.1 = 4.646$ lb. of solids per gallon of concentrate.

Then the necessary concentration ratio is found by dividing 4.646 by 0.77, or 6.034 gal. of single-strength juice will be required for each gallon of concentrate, without allowance for shrinkage or waste.

When orange juice is concentrated to 65 deg. Brix, 1 gal. of orange juice at 11 deg. Brix, weighing 8.7 lb., will contain 0.96 lb. of soluble solids. Each gallon of 65 deg. Brix concentrate weighing 11.0 lb. will contain approximately 7.25 lb. of solids. Therefore, approximately 7.43 gal. of single-strength juice will be required per gallon of concentrate without allowance for waste.

Packing and Storing.

Citrus concentrates containing more than 20 percent of moisture and less than 15 percent of citric acid are perishable foods. Fermentation may be prevented by cold storage, by added chemical preservative, or by sterilization and sealing in tight containers.

In some plants, concentrates are filled in containers in a separate room to prevent excessive contamination by spoilage organisms.

New, waxed, fir barrels with oak bung staves have been commonly used for storage at 32 deg. F. If citrus concentrates containing high percentages of sugar and acid are manufactured and barreled under sanitary conditions, 0.1 percent of

sodium benzoate will effectively inhibit fermentation in 40 deg. F. storage. The preservative is dissolved in a minimum quantity of water and added to the concentrate before removal from the vacuum pan to permit thorough mixing without aeration.

For storage of concentrates in barrels at ordinary temperatures, from 700 to 1,000 parts per million of sulphur dioxide may be added to inhibit fermentation and at the same time retard darkening and loss of vitamin C. Before the concentrates are used, the uncombined sulphur dioxide can be substantially removed by returning the concentrate to the vacuum pan and boiling for a few minutes under a high vacuum.

Pasteurized concentrates, without preservatives, have been packed in tin and glass containers. The flash pasteurization of high solids concentrates presents special problems because of viscosity. A simple method for heating the material without special equipment is to lower the vacuum in the concentrator sufficiently to permit raising the temperature to 165 deg. F., then pumping out directly to a filler. Bottom fillers are preferable and containers are filled brim-full, sealed, inverted, and allowed to stand for 5 minutes, then cooled rapidly by agitating while immersed in, or sprayed with, water.

After viscous concentrates are cooled, it is difficult to heat them in jacketed tubes of large diameter without scorching unless the tubes are equipped with helical baffles to insure uniform high velocity and agitation. In one ingenious design, the helical baffle may be moved back and forth occasionally to scrape the inside of the tube and dislodge material which tends to accumulate and overheat.

New containers are being developed for distributing citrus concentrates. Experiments are in progress with plastics and with collapsible metal tubes. It has been suggested that collapsible metal tubes will permit retail consumers to press out prescribed quantities of concentrates for reconstituting any desired number of glasses of juice, with minimum exposure of the balance of the concentrates to oxidation and spoilage organisms. Metal from empty tubes could be reclaimed.

Sanitation and Cleaning.

In no field of food manufacture are cleanliness and sanitation more important to profitable operation than in the preparation of citrus concentrates. Preservation is contingent upon protection against contamination by spoilage organisms.

Immediately after suspending plant operations, the system for handling juice and concentrate should be cleaned with hot caustic soda, trisodium phosphate or other effective cleaning solution, followed by thorough flushing with clean water to remove juice and detergents.

Stacks connecting vacuum pans and condensers accumulate traces of juice, and special care in cleaning with hot water and steam is necessary to avoid contamination of subsequently concentrated juice.

Immediately before resuming operation of the plant, water with 50 parts per million of active chlorine should be circulated throughout the entire system, followed by

Table II. Weight per Gallon of Liquids of Varying Density

Degrees Brix	Degrees Baume	Specific Gravity	Weight lb./gal.
0	0	1.0000	8.33
1.9	1	1.0069	8.38
3.8	2	1.0139	8.46
5.5	3	1.0211	8.51
7.0	4	1.0283	8.56
9.1	5	1.0357	8.63
10.8	6	1.0431	8.69
12.6	7	1.0507	8.75
14.3	8	1.0583	8.81
16.1	9	1.0661	8.88
17.9	10	1.0740	8.94
19.8	11	1.0820	9.01
21.6	12	1.0902	9.09
23.3	13	1.0984	9.15
25.1	14	1.1068	9.21
27.0	15	1.1153	9.29
28.9	16	1.1240	9.36
30.6	17	1.1328	9.43
32.5	18	1.1417	9.51
34.2	19	1.1507	9.59
36.4	20	1.1600	9.67
38.2	21	1.1693	9.74
40.1	22	1.1788	9.81
41.9	23	1.1885	9.90
43.8	24	1.1983	9.99
45.7	25	1.2083	10.07
47.6	26	1.2184	10.16
49.5	27	1.2288	10.24
51.4	28	1.2393	10.32
53.3	29	1.2500	10.41
55.2	30	1.2608	10.50
57.1	31	1.2719	10.59
59.1	32	1.2831	10.69
61.0	33	1.2946	10.78
63.0	34	1.3063	10.84
64.9	35	1.3181	10.98
66.9	36	1.3302	11.09
68.9	37	1.3425	11.18
70.9	38	1.3551	11.29
72.9	39	1.3679	11.39
74.9	40	1.3809	11.51
76.9	41	1.3942	11.61
79.3	42	1.4077	11.72
81.8	43	1.4215	11.84
83.4	44	1.4356	11.96
85.8	45	1.4500	12.08
88.7	46	1.4646	12.21

Note: In the case of pure sucrose solutions, the brix is the same as the soluble solids. In the case of citrus juices, this is not true.

sufficient hot water to remove the chlorine. When operation is resumed, the first portion of juice circulated through the system may be wasted, which often justifies its cost.

Costly losses may be avoided by:

1. Designing a separate plant building or space to afford adequate protection from insects, dust or bacteria.

2. Arranging the interior of the plant so that equipment, walls and floors can be easily and completely cleaned with steam guns and alkaline detergents.

3. Training employees and delegating responsibility to insure adequate control of cleaning operations.

4. Subjecting employees to regular medical examinations and insisting upon personal cleanliness.

5. Providing sanitary toilet facilities.

6. Removing wastes and residues promptly, and cleaning and disinfecting waste bins to retard bacterial development (creosoting aids in protecting wood in contact with waste products).

7. Protecting new barrels from bacterial contamination, and sterilizing cans and bottles before use.

8. Completing the packing operation in a tightly closed room, where special precautions are exercised to exclude spoilage organisms and insects.

9. Maintaining routine bacteriological tests on finished products.

Facilities for disposal of residues and sewage are an important consideration in the location of a plant. Pulp, seed and peel may be used in the manufacture of feeds, feed molasses, humus fertilizer, alcohol, oils, pectin glucosides and other products. Sewage may be rendered relatively unobjectionable by screening and by yeast fermentation.

Production Costs.

Citrus juice concentration is most efficiently conducted by 24 hour per day operation for 5 or 6 days per week, leaving the balance of the week for special clean-up and repair. Operated on such a basis, a plant with a capacity for handling 100 tons of fruit per day might expect production costs per gallon of 65 deg. Brix, orange concentrate to be approximately as follows:

Technical management and control	$ 0.050
Office and laboratory salary and expense	0.045
Insurance	0.012
Depreciation (buildings and equipment)	0.040
Taxes	0.030
Plant and manufacturing supplies	0.010
Repairs, replacements, maintenance	0.060
Labor	0.280
Power and light	0.028
Fuel	0.025
Water	0.020
Total	$ 0.600

This estimate is based upon average costs as follows:

Electric power	$ 0.0125	per kw.
Fuel:	0.02	per 100,000 B. t. u.
Water:	0.12	per thousand cubic feet. (Note: This price does not apply to condensing water, which is obtained from wells for the cost of pumping, or is recirculated after cooling in towers or spray ponds.)

This estimate does not include: Fruit, and fruit hauling (if separate); containers and labels; storage and shipping; sales and advertising; research and development; or miscellaneous expense.

Research and development, and miscellaneous expense may vary from $ 0.05 to $0.15 per gallon.

If essential oil is recovered from the peel, as it usually is, 10 percent of all production and fruit costs may be charged to the oil, and costs of each product may be computed separately. Because of fluctuations in peel oil prices, it is often more convenient to charge all production costs to concentrate, then deduct the market value of the oil from the original cost of the fruit in determing the total net cost of producing concentrate.

Uses of Citrus Concentrates.

Until recently, the principal use of citrus concentrates has been in the manufacture of carbonated beverage bases. the most popular of which has been orange flavored. These drinks are intended as palatable thirst quenchers, and not as substitutes for pure fruit juices. Variations in formulas are trade secrets. The best are derived entirely from fruits excepting for minor constituents such as gums, stabilizers, color and salt. Typical combinations include: Orange, lemon, grapefruit and pineapple concentrates, decreasing in the order listed, to give rounded body and fruity character. To this mixture is added a gum-stabilized emulsion of a mixture of vacuum concentrated, cold pressed citrus oils which may be in the following proportion:

	Percent
Threefold-concentrated orange oil	90
Threefold-concentrated lemon oil	9
Fivefold-concentrated lime oil	1

A small quantity of pasteurized, screened juice from freshly crushed whole oranges may be added to restore freshness. Other constituents may include salt, preservative and artificial color. The bottle mixes 1 gal. of this base with 10 to 18 gal. of simple sirup. A measured "throw" is placed in bottles, which are then filled with carbonated water and capped. Carbonation ranges from $1\frac{1}{2}$ to $2\frac{1}{2}$ volumes of carbon dioxide.

Lemon and lime rickeys are also popular; and citrus concentrates are used in other flavors including root beer, ginger ale and colas. Carbonation of such beverages ranges up to four volumes of gas.

Other uses of citrus concentrates include the manufacture of frozen desserts, bread spreads, bakery goods (fruit cakes and cookies), cocktails, sauces and candies.

Drink stands and dairies have used blends of orange and lemon concentrates in the preparation of acceptable fruitades, but some of these products have been so poor in flavor as to curtail the volume of sales.

Interest is now focused upon the use of citrus concentrates in the preparation of reconstituted fruit juice drinks, in which the concentrate is diluted to its original soluble solids content and consumed as a substitute for fresh or canned juice. This use increases the importance of controlling quality during manufacture, storage and distribution, and renews interest in the improvement of flavor by better manufacturing methods.

Until a method is developed for returning volatile juice-flavoring constituents, tested portions of vacuum-concentrated cold pressed peel oil should be added to citrus concentrates intended for use in preparing reconstituted juice. This offsets flatness without adding ingredients foreign to the fruit, although label declarations are required by food and drug regulations.

Reconstituted citrus juices may be bottled in equipment similar to that used for carbonated beverages. The concentrate, diluted with enough warm water to permit use in a siruper, is "thrown" in bottles which are then filled with hot water after which the bottles are capped and inverted to mix the concentrate and water, and pasteurize the product.

Another development in which concentrated citrus juice may play an important part is in the production of dehydrated juices. Lemon juice is now prepared in powdered form after mixing with considerable portions of corn sirup or powdered milk. Various spreading agents are being investigated in an effort to develop a method for preparing powdered orange juice, probably using orange concentrate as the raw material and completing the dehydration in special equipment. Vacuum-concentrated essential oil will probably be added to the powder.

A patented use for orange concentrate is in combination with anhydrous dextrose

which will absorb 8 percent water of crystallization (8). Four parts of anhydrous dextrose may be mixed with one part of a 70 deg. Brix orange concentrate to make a solid product which may be used in confections, jelly powders, punches, fruitades or other products. Owners of the patent license it without royalty to manufacturers using their dextrose.

Summary.

Methods for the vacuum concentration of citrus juices are described. Manufacturing costs are itemized and uses of citrus concentrates are discussed.

Acknowledgment.

The author appreciates the helpful suggestions made by H. W. von Loesecke.

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